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Details of railroad truss-bridges

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DETAILS OF RAILROAD TRUSS-BRIDGES

BY

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This is to certify that the thesis of PAUL FREDERICK JERVIS entitled Details of Railroad Truss-Bridges is approved by me as meeting this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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Professor of Civil Engineering.

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DETAILS OF RAILROAD TRUSS-BRIDGES.

INTRODUCTION.

The purpose of this thesis is to present a brief review and a discussion of a comparison of the standard details for short-span railroad bridges. Simple truss spans up to 250 feet only have been included in this comparison; spans over this limit not being considered because of the use of uncommon details for special designs.

The standards and specifications investigated were those of the following railroads: Northern Pacific; Atchison, Topeka and Santa Fe; Illinois Central; Wabash; and Michigan Central. Besides these, several partially complete standards of other leading railroads in the United States were considered. The standards and specifications of the American Bridge Company and the Phoenix Bridge Company were also investigated. The excellent literature in engineering magazines and text-books has been drawn upon for much valuable information.

In the presentation of this subject, the details of through pin-connected trusses will be discussed in full. The details of the deck pin-connected trusses wherein they differ essentially from those of the through pin-connected, will then be discussed. Following this the details of the through and deck riveted trusses will be considered.

It is not the aim of the writer to fully discuss the last two types of trusses, as it would necessitate needless repetition, owing to the similarity of many of the details of the pin-connected and riveted trusses. Merely those details that are necessarily

different will be considered.

Sketches of the details discussed have been drawn where they were necessary,but no special effort has been made to make these details to scale,their purpose being merely to make the discussions clearer and more comprehensive.

END POST AND UPPER CHORD.

While there is enough variation in stress in a simple truss with parallel chords to admit of considerable difference in the size of the chord members,it is almost universal practice to have the end post and upper chord of the same general dimensions. However,there are a few cases in which the end post is wider than the upper chord,the object of this being to provide for the flexural stress due to wind. The arrangement which has the end post and upper chord of uniform size has several important points in its favor,the most important of which is that it is cheaper than any other arrangement; since it simplifies such details as the splicing,the lacing,the rivet spacing,and the templet work. This simplification of details lessens the cost of construction,both in the shop and in the field.

The cross-section of the end post or upper chord of nearly every bridge investigated shows that these bridges were designed with equal moments of inertia about their horizontal and vertical axes.

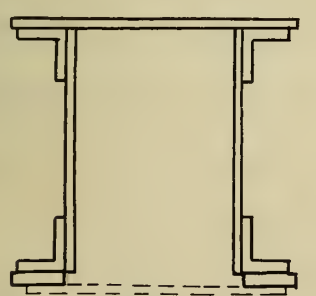


Fig.1

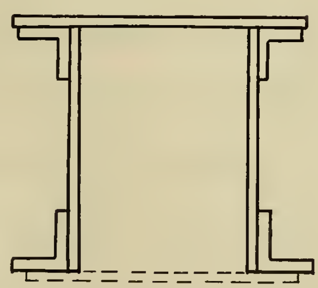


Fig.2

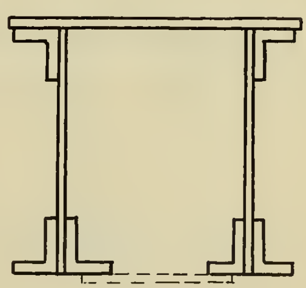


Fig.3

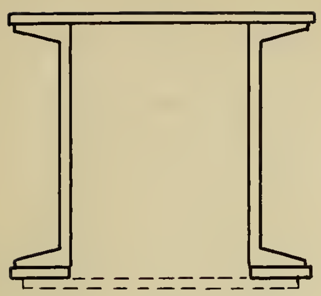


Fig.4.

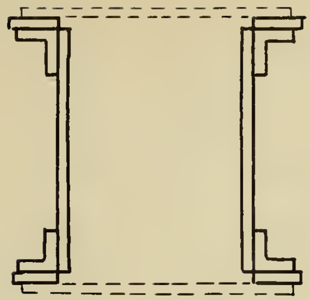


Fig.5.

Fig.2 is the most common section for spans between 125 and 175 feet. This section is composed of two built-up channels, one cover plate,and lattice bars. The built-up channel consists of a web plate and two angles,the lower anglesbeing much heavier than the upper ones. The purpose of having the lower angles the heavier is to avoid eccentricity of the section. Where all of the angles are equal,as is the case in Fig.1,flats are riveted to the bottom of the horizontal leg of the lower angles,to balance the section. Fig.3 shows a good method of balancing the section which is used by the Northern Pacific Railroad in their standard 200-foot Pratt truss. One advantage of this method is that it produces greater stiffness in the member and reduces the stress in the lacing bars which are riveted to the horizontal leg of the inside angles. A disadvantage of such an arrangement is that the extra angles must be clipped,thereby increasing the shop cost.

One of the simplest sections for an upper chord or end post is that shown in Fig.4. The flats fastened to the bottom of the channels are used to balance the section about an axis perpendicular to and passing through the centre of the channel webs. These are often omitted,but unbalanced sections are not considered good design. When the section is so small that the required thick-

ness of metal is less than the minimum allowed in the specifications, lacing bars are used on the top and the bottom of the member, the cover plate and flats in such cases being omitted.

In all of the sections described above, the necessity of increasing the sectional area towards the center of the span is met in each case by riveting an extra plate to the web.

The cover plate has an advantage in that it stiffens the member and is capable of resisting stress. It also has the disadvantage of causing stress due to eccentric bearing. The stresses due to eccentricity are generally avoided by balancing the section with angles or flats; or in case of short spans, these stresses are counteracted by placing the pin at the neutral axis. However, if the pin is placed off the neutral axis, provision must be made for clearance of the eye-bar heads at the joints.

The general practice for the use of lattice bars is to incline them 60 degrees to the axis of the member for single lacing, and 45 degrees for double lacing. Lattice bars are used merely to stiffen the member, their size being determined by general practice and experience. All latticed members are stiffened by batten plates at the ends and often at the center. In all of the cases investigated these plates had a minimum thickness of three-eighths of an inch; but in some cases their width was not equal to that of the member. The latter condition is not in accordance with Cooper's specifications.

Pin plates are used at the joints for the double purpose of reinforcing the member to provide for the metal cut away and of reducing the unit pressure on the pin. They should be of such size as to properly contribute, through the rivets, the pressure carried

by them to the flange and web of the member. At least one plate on each side of the member should extend six inches or more within the batten plate at the end, to provide for not less than two transverse rows of rivets.

LOWER CHORD.

In nearly all of the cases investigated it was noted that the lower chord, with the exception of the two panels at each end, was composed of eye-bars. Owing to the possibility of a reversal of stress in the lower chord, due to the sudden application of the brakes on a moving train passing over the bridge or to the thrust of a derailed car, the first two panels at each end are usually composed of built-up sections. Another reason for using these built-up sections is that they reduce the vibration.

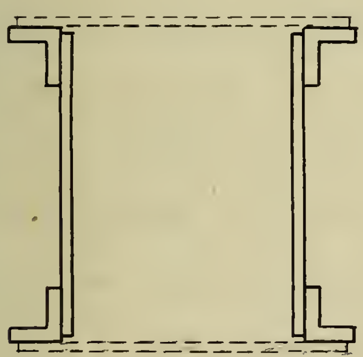


Fig.6

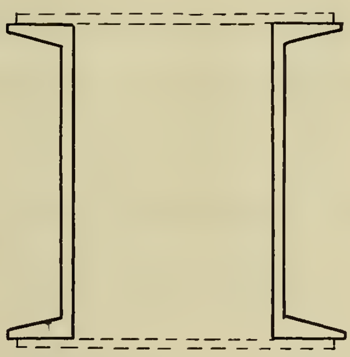


Fig.7

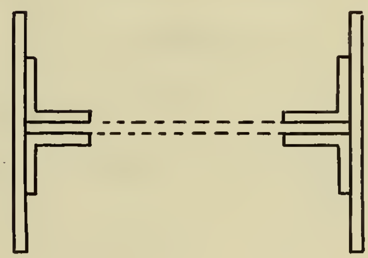


Fig.8

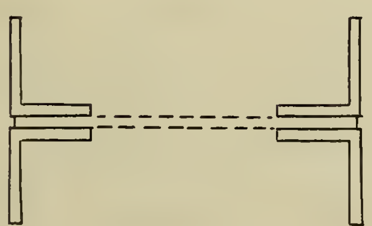


Fig.9

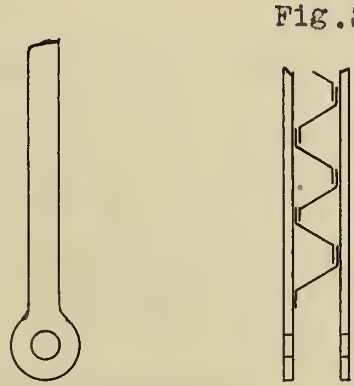


Fig.10

The most common sections for the built-up lower chords are shown in Fig.6 to Fig.9. The sections composed of built-up channels or rolled channels, as shown in Fig.6 and Fig.7, are used much more than those built as shown in Fig.8 and Fig.9. When necessary, the area of the first two sections shown is increased by riveting plates to their webs. The batten plates and lacing bars of the built-up lower chord members are similar to those of the end post and upper chord. The distance from the back of the pin hole to the back of the member should in no case be less than the radius of the pin. The lower chords in a few cases investigated consisted of built-up members from end to end. In such cases the floor system is often attached to it.

When eye-bars are used and it is desired to make them more rigid, they are laced together with bent bars as shown in Fig. 10. This, however, reduces the effective area of the eye-bar. Sometimes the eye-bars extend across the first two panels at each end of the truss, and are prevented from sagging in the middle by shelf angles attached to the hip-vertical. The only objection to these long eye-bars is that extra precautions must be taken to prevent them from being bent, either in shipment or in erection.

INTERMEDIATE POSTS.

The most common form of intermediate post consists of two channels fastened together by lattice bars and batten plates. The sections shown in Fig.11 and Fig.12 are used very extensively. They are composed either of built-channels or rolled channels. When their flanges are turned out, as is the older practice, it is necessary to clip them at the ends to provide space for packing

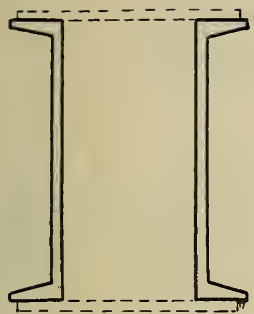
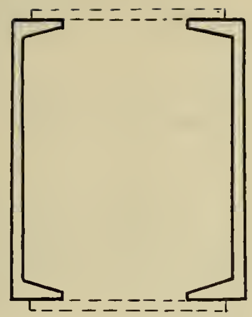
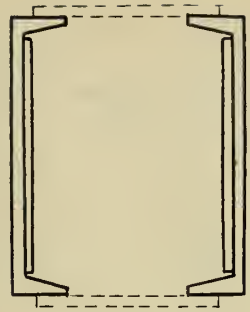
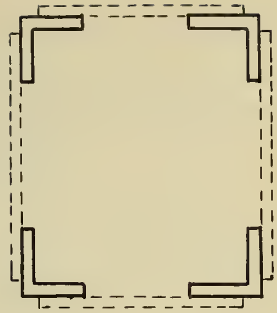





Fig.11. Fig.12. Fig.13 Fig.14.

the joints. The section shown in Fig.12 is used by the Northern Pacific and many other railraods which have changed their standards within the last ten years. This design is better than the one shown in Fig.11,because it is a stronger column for the same out to out measurements,and further,the unnecessary clipping of the flanges of the channels at the joints is avoided. When additional area is required,the section is increased by riveting one or more plates,preferably on the inside of each channel,as is shown in Fig.13. A section which is seldom used is shown in Fig. 14. It is composed of four angles fastened together by lattice bars,placed either on the outside or inside of the angles. The chief disadvantage of this form of intermediate post is the difficulty of building a diaphragm which will equally transmit the stress of the lateral struts and floorbeams to all four angles.

A common method of packing the intermediate post at a joint of the bottom chord is shown in Fig.15. The intermediate post in this case is built of laced channels. It will be noticed that the members are packed as near the end as possible to reduce the bending moment on the pin. The members are also arranged symmetrically with respect to the center line of the pin.

Fig.16 illustrates the manner in which a joint at the top

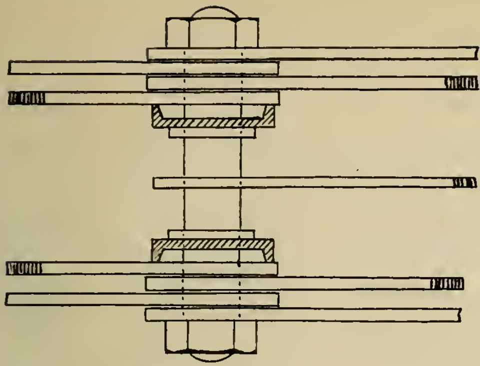


Fig.15.

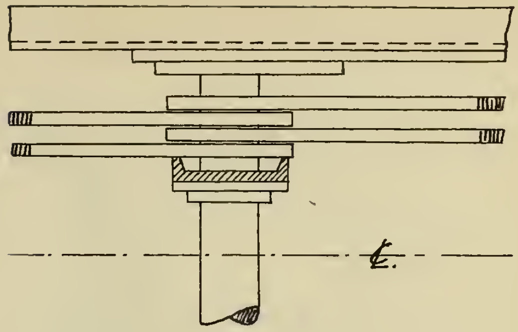


Fig.16.

chord of the same bridge is packed. The intermediate post in this case is packed nearest to the center of the pin. This arrangement tends to neutralize the bending moment on the pin; since the vertical component of the tensile stress in the diagonals counteracts the compressive stress in the post. It is almost universal practice to pack the joints in a manner similar to that shown in Fig. 15 and Fig.16.

HIP-VERTICALS.

The hip-vertical receives impact more directly than any other member of the truss. Many railroads avoid excessive vibration resulting from this impact by making the hip-vertical a rigid riveted member. For example,the Atchison,Topeka and Santa Fe and the Northern Pacific Railroads use latticed channels,while the Michigan Central Railroad uses a section similar to that shown in Fig.17. The hip-vertical shown in Fig.17 consists of two pairs of angles,laced together above the floorbeam and fastened together by a diaphragm at the floorbeam connection. This type of hip-vertical is,however,often modified by substituting a web plate for the lattice bars. The form shown in Fig.18 is used by some of the eastern railroads. It consists of two hangers fastened together by a diaphragm and suspended from the upper chord pin by latticed eye-bars.

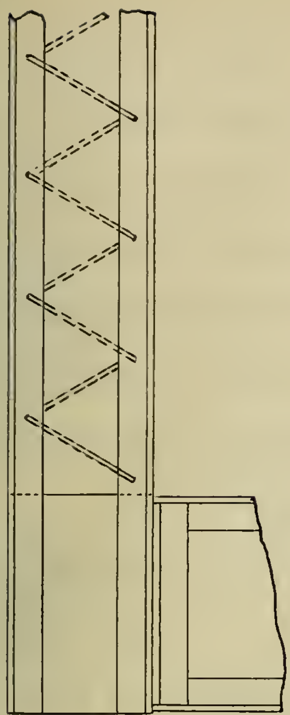


Fig.17

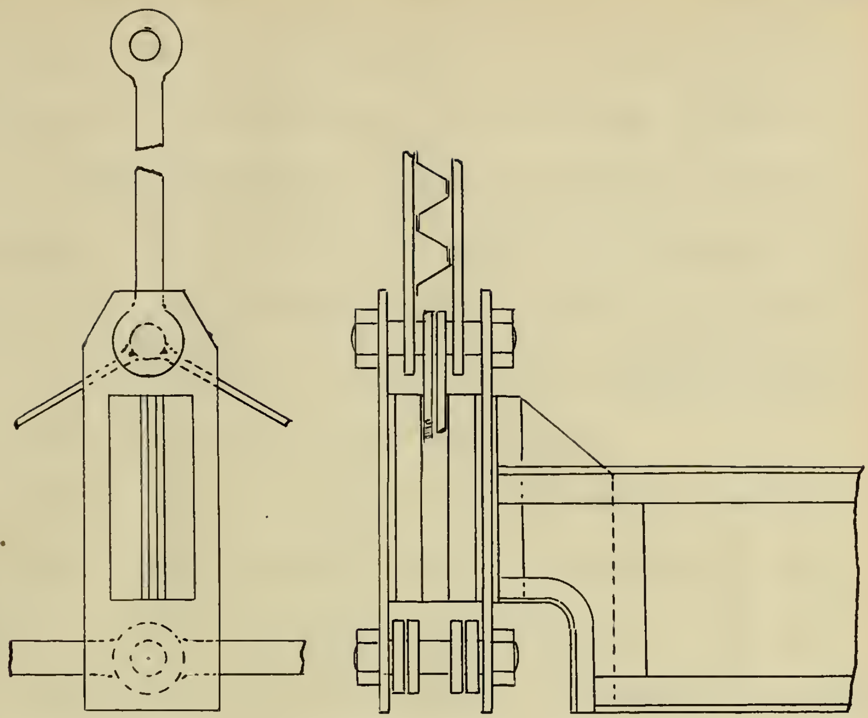


Fig.18.

This type of hip-vertical is not stiff enough to prevent tilting of the floorbeam,which is attached to it. A very efficient method of preventing this tilting is to use loop-bars attached to the hip-vertical,as is shown in Fig.18. The other ends of these loop-bars are fastened to the pins at the pedestals and at the second panel points. Of these three general types of hip-verticals,the one composed of latticed channels is the best; since its stiffness lessens the vibration and in case of a flood tends to prevent buckling of the floor by the driftwood.

FLOORBEAMS.

The floorbeams in all of the bridges investigated consisted of short plate girders,each girder being constructed of a web plate and four flange angles. The depth of these girders varied from three to six feet, depending principally upon the panel length,

width of bridge,and the live load. Extreme depth of the floorbeams on a through truss-bridge should be avoided,as it necessitates a corresponding heightening of the trusses. On the other hand the floorbeams should be at least three feet deep to provide for sufficient riveting space for the web splice. Another important reason for taking three feet as the minimum depth is that the large section modulus required to sustain the modern engine loading can be obtained more economically by using deep floorbeams.

In through trusses part of the end floorbeam is usually cut away to give clearance to the lower chord. When this is done, the web must be spliced so that it may extend upward far enough to provide the required space for rivets in the end connection angles.

The most common forms of floorbeam connections are shown in Fig.19 to Fig.21,that shown in Fig.19 being the most used.

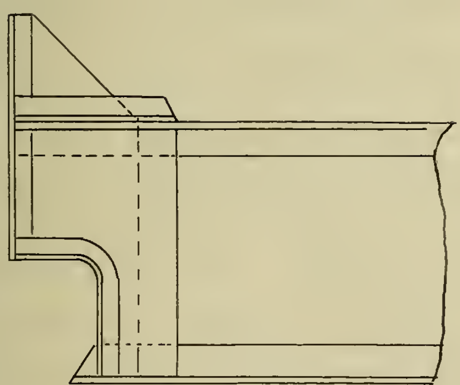


Fig.19.

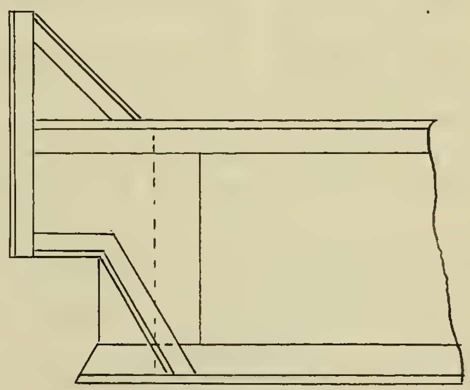


Fig.20.

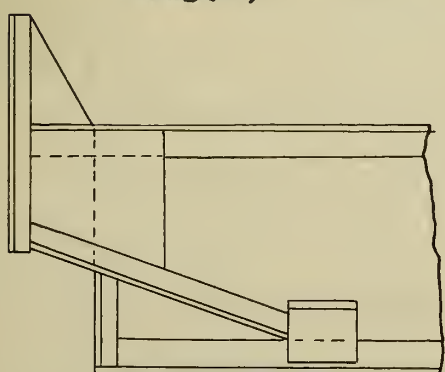


Fig.21.

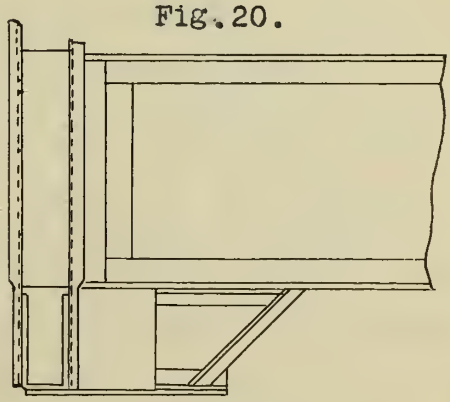


Fig.22.

In each of these three cases the splice plates are continued to the end so as to act also as filler plates and to aid in strengthing the web around the cut. The main difference in these three different connections is in the arrangement of the short slanting reinforcing angles around the edge of the cut at the end of the floorbeam. In Fig.19,these angles are curved,while in Fig.20 they are practically straight. As to which is the better,the curved or the straight reinforcing angles,it is merely a matter of judgment. The latter,however,are cheaper,but notwithstanding this,several of the larger bridge companies have adopted the use of the curved angles. The principal purpose of these reinforcing angles is to stiffen the web around the cut.

When part of the web has been cut away to give clearance to the lower chord,the bottom of the intermediate post and the bottom of the intermediate floorbeam are always placed on the same level. A large bending moment due to the eccentric connection of the lower lateral system can thus be easily avoided by rigidly fastening the floorbeam to the intermediate post by means of a large connection plate. Another method of reducing this bending moment is shown in Fig.22. In this case a web plate stiffened by angles is fastened to the lower flange of the floorbeam,and is connected at the bottom to the large lateral connection plate. This plate is also attached to the bottom of the intermediate post.

A diaphragm consisting of a web plate and four connecting angles should always be riveted to the inside of the intermediate post to transfer the load of the floorbeam equally to both sides of the post. This diaphragm should have a minimum length equal to that of the floorbeam connection angles. The general method of

riveting the diaphragm in place is shown in Fig.18.

Within the last ten years,the use of end floorbeams has nearly superseded that of other forms of construction employed to support the end stringers. End floorbeams have an advantage over the form of construction in which pedestals are used in that they require less complicated details and are less liable to distortion.

The end floorbeam is usually four or five inches deeper than the intermediate floorbeam. This extra depth is not given to provide for an increase in the loading, - for the load is only half of that on the intermediate floorbeam - but to make it deep enough to rest directly upon the masonry plate.

Fig.23 shows a method of connecting the end floorbeam to the end post. In this case,the floorbeam is secured by a gusset plate to prevent any movement due to the lateral thrust of a train passing over the bridge.

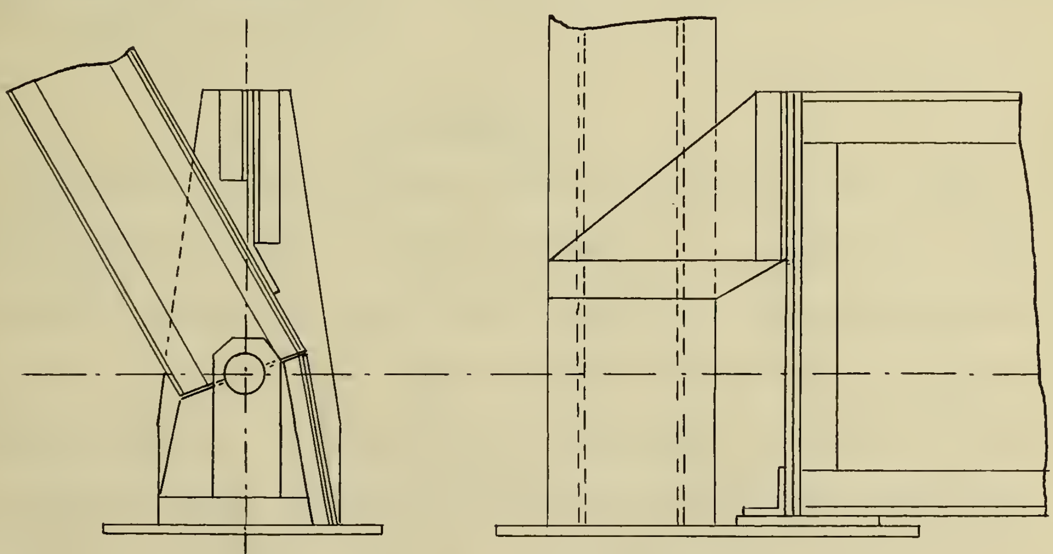


Fig.23

It will be noticed from the nature of this connection that its only use is to keep the floorbeam in place. It does not transmit any of the load; since the load is carried directly to the masonry

plate by the floorbeam. The general method of connecting the end floorbeam, shown in Fig.23, is used by a large number of railroads.

When no end floorbeam is used, the end stringers rest upon cast-steel pedestals or upon supports which are riveted to the stringers, as shown in Fig.24. This latter method has been adopted by the American Bridge Company. The end stringers are fastened at

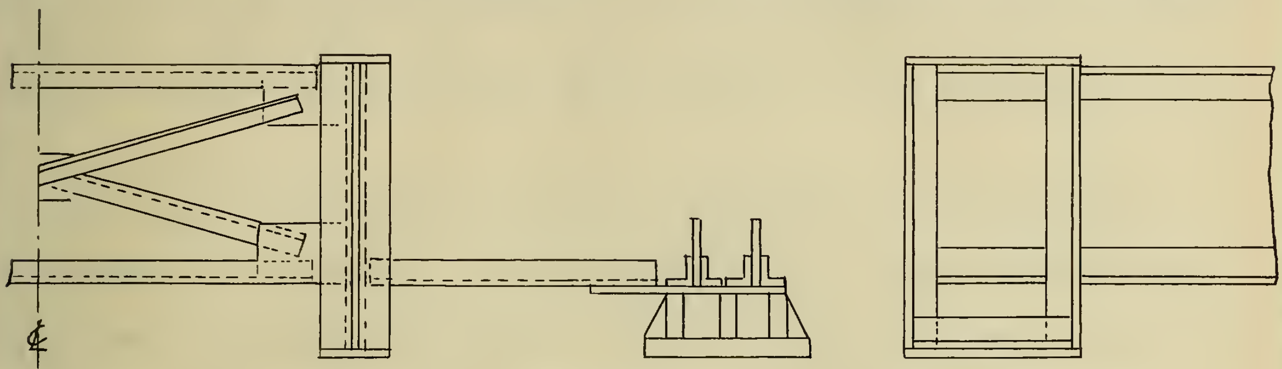


Fig.24.

the ends by a cross-frame and the lateral shifting of the stringers is prevented by connecting them to the pedestals by means of angles, as is shown in Fig.24.

STRINGERS.

In through truss bridges there are usually two lines of stringers, composed either of plate girders or of I-beams. They are placed six and one-half to eight feet apart, and support the floor, the track, and the live load. The use of I-beams for stringers is hardly commendable, as more than one I-beam must be used to withstand the modern engine loading, and, as the rails are generally placed eight to ten inches inside of the stringers, there will be some deflection of the ties. This deflection will cause the I-beams nearest the center to receive more than their share of load. Again, if the I-beams are placed close together, as they should be, it is impossible to use two connection angles for every I-beam.

A few railroads use four stringers,the main stringers being placed directly under the rails,while the safety stringers are placed about two and one-half feet outside of the main ones. This arrangement is better than the I-beam construction,as there is very little deflection of the ties. The most common stringers are those consisting of two single lines of plate girders. The latter system is free from the objections cited for the I-beam stringers,and is more economical than the system having four lines of plate girders to a track.

In long panels,the stringers are fastened together by a lateral system of the Warren type, attached to the upper flanges and also fastened by one cross-frame in the center of the panel. In short spans,either the lateral bracing or the intermediate cross-frame is omitted,depending upon the judgment of the designer.

The simplest and most common method of connecting the stringers to the floorbeams is shown in Fig.25. Here the webs of the floorbeam and stringer are connected by a pair of angles as shown. In addition to these,shelf-angles are riveted under the ends of the stringer. The method of connecting the I-beam stringer

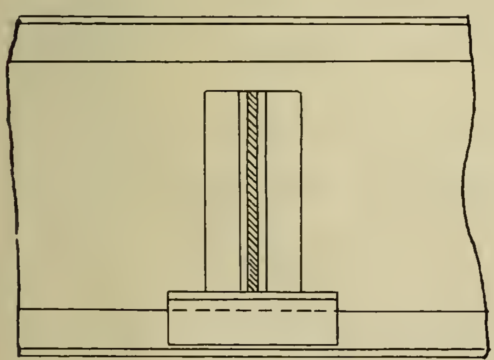


Fig.25.

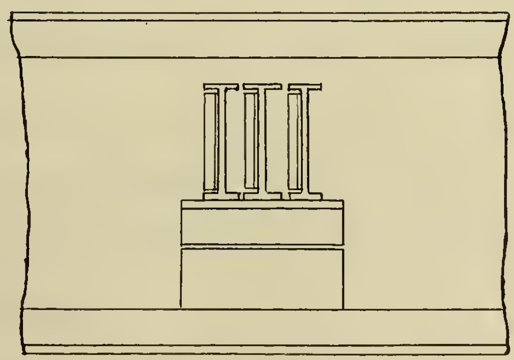


Fig.26.

is shown in Fig.26. In this case all of the I-beams are assumed to be equally loaded. Only one connection angle is used at the

end of each I-beam, and a shelf-angle is here necessary to prevent the twisting tendency due to the eccentric connection.

In a few cases the web of the floorbeam has been cut in order to connect the top flanges of the two adjacent stringers, this being done to avoid tension in the rivets connecting the stringer to the floorbeams. Such a connection as this is advisable when the panels are long; since the deflection of the stringer will cause a large stress in the connection.

The stringers are usually placed at such a height that when the cross-ties are laid upon them, the top of the floorbeam will be an inch or two below the tops of the ties. Such an arrangement is desirable as the space between the ties at the floorbeam is too great to allow a derailed car to safely pass over it.

FLOORS.

In short railroad bridges the floor is usually left open. These open floors consist merely of wooden cross-ties, which are used to support the rails. Sometimes all of the ties extend the full width of the bridge to provide for a foot-way; but often only the alternate ties are extended.

Within the last few years, the use of open floors has been on the decline, solid floors being used in their place. The latter includes many different types of continuous metal floors which support the rails and cross-ties and also carry the ballast in which the ties are usually imbedded.

A type of flooring, which the New York Central and Hudson River Railroad has adopted for through bridges and which many other railroads are using, is shown in Fig.27. The advantage claimed for this type is that its ends can be fastened to the trusses more

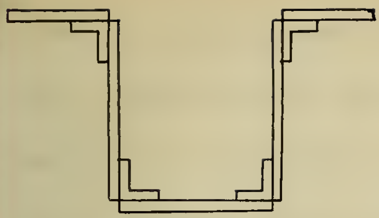


Fig.27

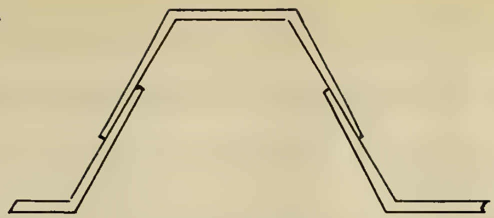


Fig.28

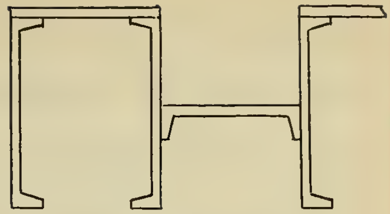


Fig.29

readily than any section having inclined sides such as[15] shown in Fig.28. Further, the depth and width of the section can be easily changed by using plates of different widths. This section, however, requires eight rows of rivets, while the section shown in Fig.28 requires only two. The New York Central and Hudson River Railroad requires, in its standard deck-truss bridges, the use of a splayed channel section similar to that shown in Fig.28. This section is also used in the floor of the Willamette Bridge at Portland, Oregon. Fig.29 shows a rectangular trough-section composed of channels and plates, and is used in the Wells Street Bridge, Chicago, Illinois. In this bridge the ties are laid directly into the troughs and no ballast is used. This type of flooring is often modified by omitting the horizontal channel and riveting a plate to the bottom flanges of the channels. These trough sections, which are composed of channels, require only half as many rivets as the sections composed of plates and angles.

Two less common types of floor are the triangular trough floor, composed of angles and plates, and the trough floor composed of rectangular Z-bars and plates. These two types are difficult to connect to the trusses.

In the cities where bridges are used in track elevation, it is required that the flooring be as impervious as possible. When metal floors are used, this requirement is usually fulfilled by

filling the troughs with an asphaltic mastic. The New York Central and Hudson River Railroad specifies that an asphaltic mixture shall be used in all of its bridge floors. The metal trough floors have an advantage over open floors in that they are capable of reducing the stress in the bottom lateral bracing.

TOP LATERALS.

It was found by investigating the standards of the different railroads that the top laterals were, in nearly every case, composed of angles. In short spans, the laterals usually consist of one angle or of two angles placed back to back. These angles are generally attached to the upper chord, as is shown in Fig.30. A very efficient type of bracing is shown in Fig.32. This type is composed of two angles latticed together and attached to the upper and

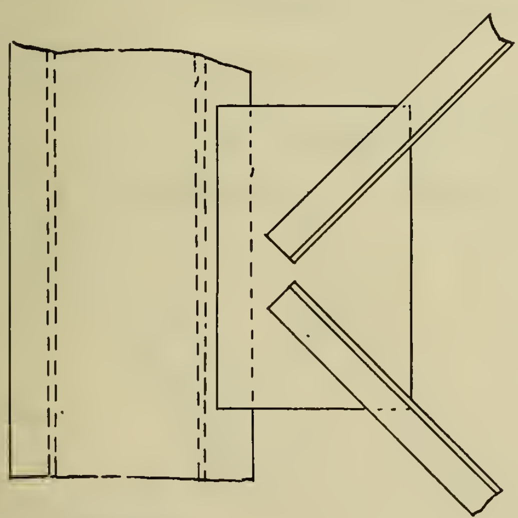


Fig.30.

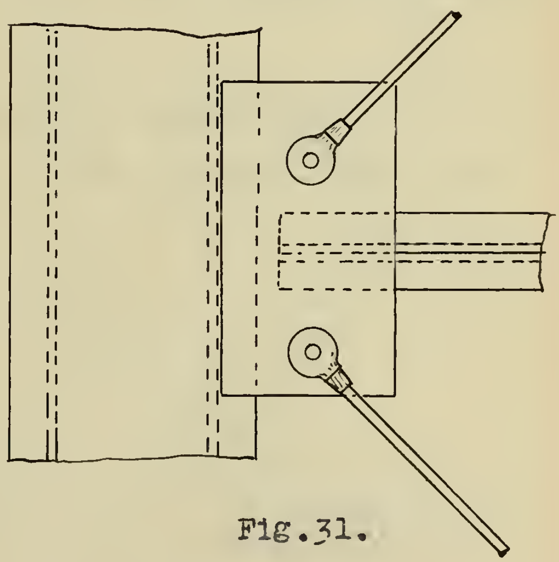


Fig.31.

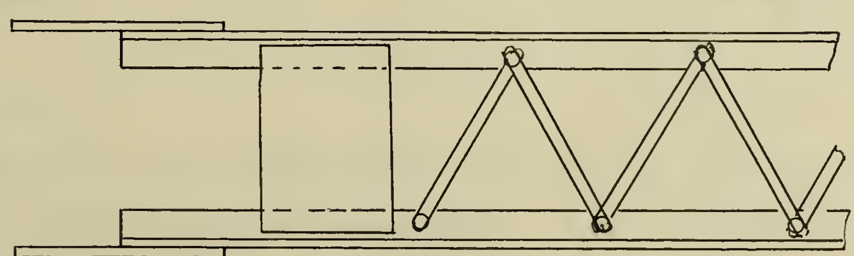


Fig.32.

lower flanges of the top chord. The advantage of fastening this bracing to both the top and the bottom of the chord is that an eccentric connection is avoided.

Fig.31 shows the type of top lateral bracing used by the Northern Pacific Railroad. Here,adjustable rods are used,which are attached to the lateral connection plate by means of a clevis and pin. The principal disadvantages of the adjustable rods are that they lack rigidity and that they cannot,without great care,be maintained in their proper adjustment. Those now using the adjustable rods claim they are not only lighter,but that the upper chord can be more thoroughly lined up by their use.

The bottom lateral bracing consists in all cases of angles which are fastened to the connection plates at the ends of the floorbeams. In short spans,single angles are used; while in long spans where the stress is considerable,it is customary to use two angles placed back to back.

The usual method of fastening the lateral angles at their point of intersection is shown in Fig.33 and Fig.34. When both

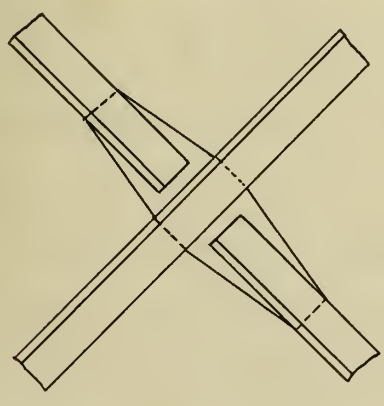


Fig.33.

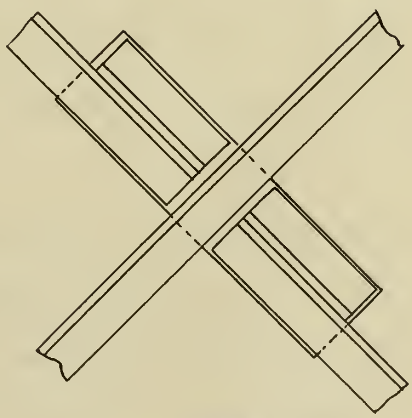


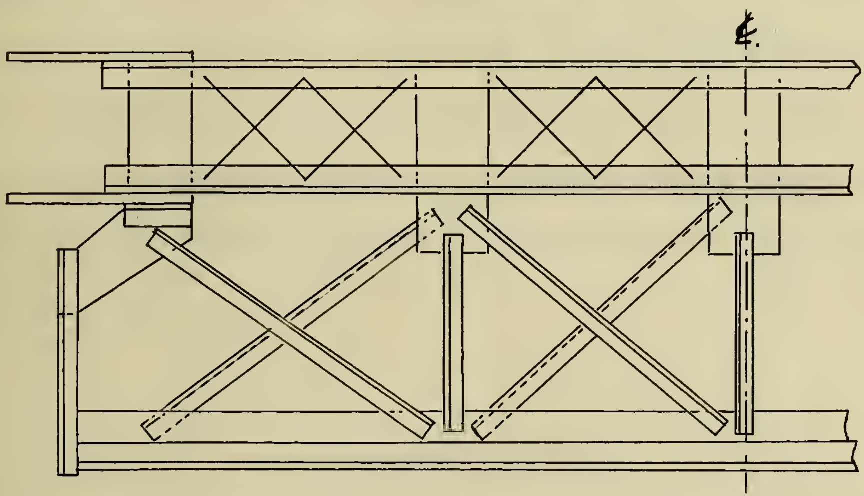
Fig.34.

legs of the angles are considered effective in determining the net section,clip angles must be used at all connections. Such an arrangement is shown in Fig.34. The lower laterals should be fasten-

ed to the stringers to prevent them from sagging.

TOP LATERAL STRUTS AND SWAY BRACING.

The top lateral struts usually form a part of the sway bracing. The lateral struts for short spans are in most cases composed of two pairs of angles, placed back to back, and laced together, as shown in Fig.35, their depth being equal to that of the upper chord. The angles composing the top lateral strut are generally riveted to the upper and lower flanges of the top chord by means of gusset plates. Sometimes, however, the upper pair of angles extends



- Fig.35.

across the top of the chord and is riveted directly to it. Occasionally a solid web plate is used instead of lacing bars to connect the two pairs of angles.

When no sway bracing is used, the top lateral strut is so constructed that it is capable of performing the function of the sway bracing. In such cases the bottom pair of angles of the strut are attached to the intermediate posts instead of to the lower flange of the top chord.

There are two general methods used for bracing the top lateral struts. In one case, angles extend diagonally across the

entire length of the strut. When this method of bracing is used, the upper and lower horizontal angles are supported in the middle by connecting them to the diagonals. In the second case,the strut is divided into two or three panels. These panels are cross-braced by means of two diagonal angles. The latter method has an advantage over the first in that it gives more rigidity,and is more effective where it is necessary to have a shallow system of sway bracing.

Where there is a small clearance,knee-braces are generally used in the sway bracing. These knee-braces are fastened to the bottom flanges of the top strut and to the intermediate post. They are often composed of two angles placed back to back; and are supported in the middle by means of a short angle,which is attached at the upper end to the top chord. Occasionally they are supported by a solid web plate.

PORTAL BRACING.

Many different types of portal bracing are used in through truss-bridges. This is probably due to the fact that the standardization of their details has been retarded by an effort on the part of the different designers to give the portal an artistic effect. The general tendency at present is to use as few members as possible in the construction of the portal bracing. While some of the more complicated forms may be better from an aesthetic point of view,they are less economical and often less effective than the simpler types of bracing.

The most efficient type of portal is shown in Fig.36. In this case a relatively low attachment to the end post can be secured

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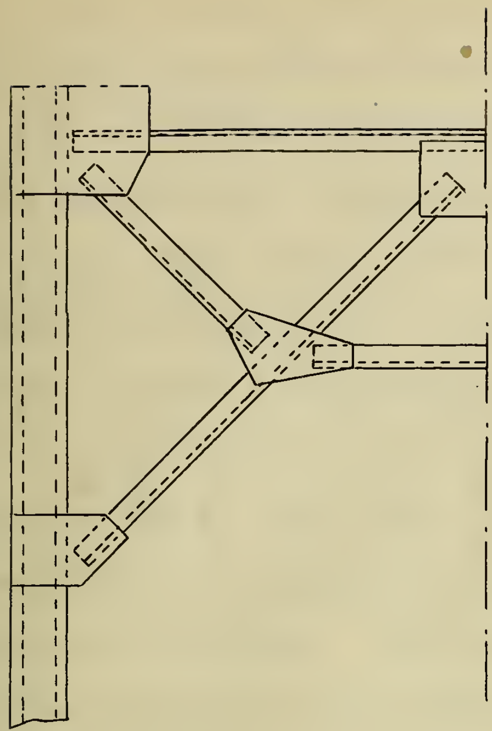

Fig.36.

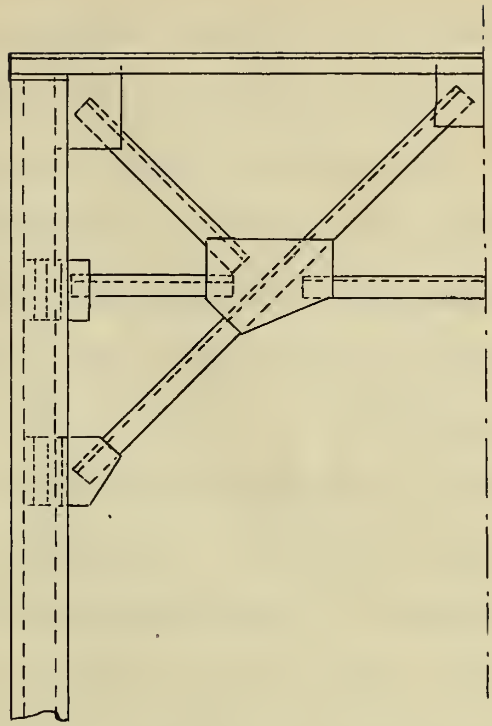

Fig.37.

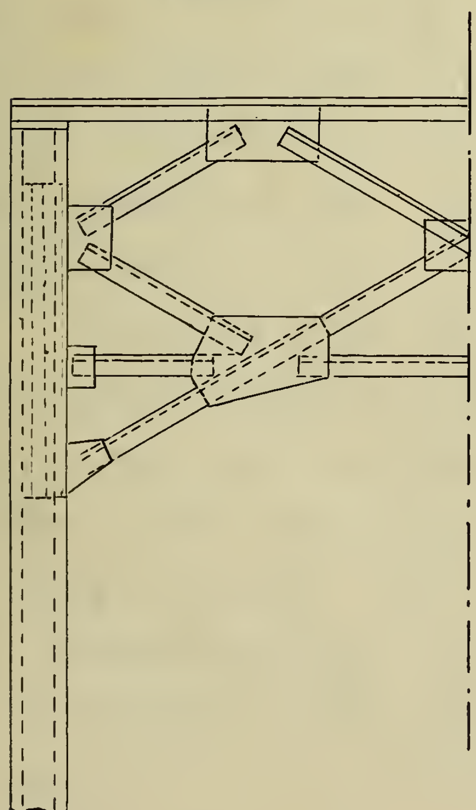

Fig.38.

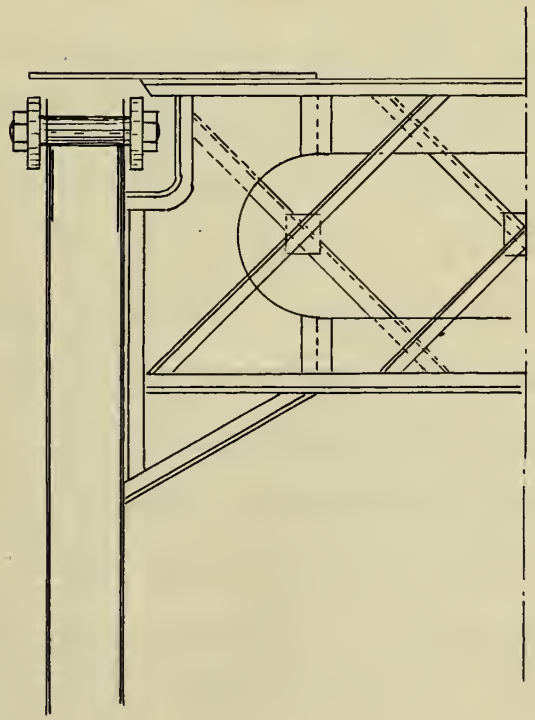

Fig.39.

This feature is desirable, since the stress transferred at the foot of the knee-brace causes considerable bending moment in the post. In this type of bracing the top strut and long diagonal are the only members which carry stress. The other two members act merely as stiffeners. This type of portal is composed of angles, and they are fastened to the end post in three different ways; (1) they may be attached to upper flange only; (2) they may be attached to both upper and lower flanges; or (3) they may be fastened to the centers of the end posts. The latter is the most common method of fastening the portal bracing, and it has an advantage in that an eccentric connection is avoided. The principal disadvantages of connecting the portal bracing at the centers of the end post are that the rivets connecting it to the posts are in the tension; and further, an expensive diaphragm is necessary at the connection to transfer the stress equally to both sides of the posts. The first method is adequate when small stresses are to be transferred; but when they are large and the head room is small, it is advisable to use a double system of portal bracing. In this case one system is attached to the bottom and the other to the top of the end post.

Fig.37 and Fig.38 show forms of portal bracing that the American Bridge Company use extensively. It will be noted that these two forms are very similar to that shown in Fig.36. When the head room is very limited small plate girders are sometimes used for bracing the portal. The use of latticed portals is very common. A well designed portal of this type, which is used by the Northern Pacific Railroad, is shown in Fig.39. Small knee-braces are used in this case.

PEDESTALS.

The pedestals transfer practically all of the weight of the bridge and the live load to the abutments. Therefore great care should be taken in detailing them; since the load must be uniformly distributed over the masonry.

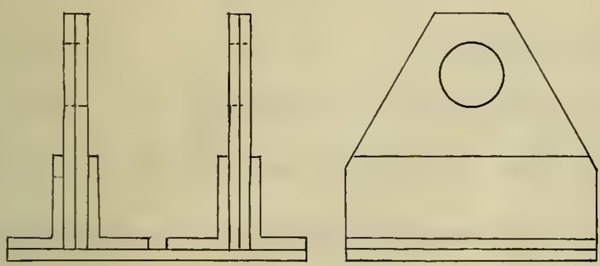

Fig.40.

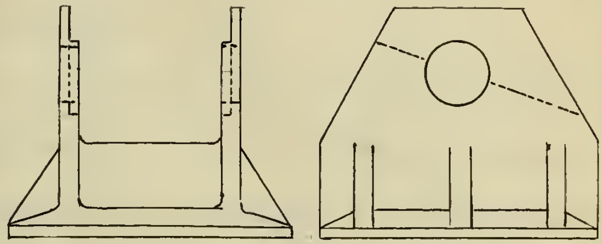

Fig.41.

Fig.40 shows a pedestal used extensively for short spans. It consists of bolster-plates riveted by means of angles to a shoe-plate. The total thickness of the bolster-plates is governed by the required amount of bearing area on the pin. The two inside angles are often omitted,but the rivets connecting the bolster-plates and the angles must carry the load in single shear;whereas when the angles are placed on both sides of the bolster-plates,as is shown in Fig.40,the rivets are subjected to double shear. One pair of bolster-plates extending around the pin is commonly used.

Fig.41 shows a very efficient cast-steel pedestal used by the Northern Pacific Railroad in their standard two-hundred-foot through-bridges. The bolsters of these pedestals are packed inside of the lower chord and end post. The inner sides of the bolsters near the top are cut down to the center of the pin,as is shown in Fig.41. This is done so that the greater part of the end post section can be packed directly over the bolsters. The use of cast-steel pedestals is very common among the railroads that do not per-

mit their designs to be governed by the specifications of the bridge companies. Cast-steel pedestals are more economical and more rigid than those built of steel shapes; but they are liable to become cracked when subjected to shocks or large eccentric loads.

ROLLERS AND PLATES.

In bridges over eighty feet in length, rollers must be used, in order that the expansion and contraction of the trusses, produced by changes of temperature, will not damage the bridge or the masonry. There are two general types of rollers, the circular rollers, and the segmental rollers.

Fig. 42 shows a nest of circular rollers, which rest directly upon the masonry plate. The masonry bed-plate and the shoe-plate of the pedestal have narrow plates attached to their bearing surfaces, which fit into the grooves in the rollers. The Z-bars on the sides hold the rollers in place and prevent lateral movement of the pedestal. The angles at the ends tend to prevent dirt from getting in-

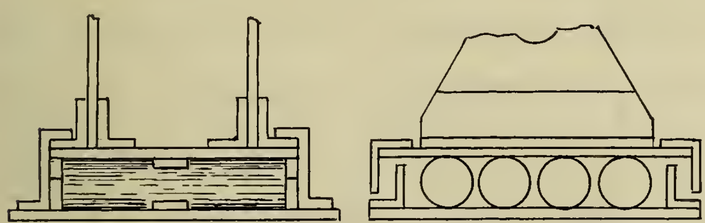

Fig. 42.

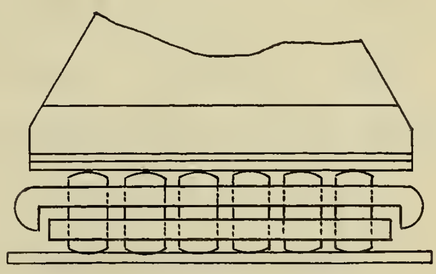

Fig. 43.

to the roller-nest.

The rollers for railroad bridges should be not less than six inches in diameter. If smaller rollers are used, the nest is liable to become clogged with rust and become useless. The size and required number of rollers depend upon the amount of stress trans-

mitted by the shoe-plate.

In long-span bridges a large number of rollers are necessary to give sufficient bearing area. Segmental rollers are usually employed to reduce the size of the bearing plates and pedestals. A common type of segmental roller nest is shown in Fig.43. The distance between the centers of the rollers is usually about one-half of their height. Contact between the parallel sides of the rollers prevent them from tipping over; but an additional provision against tipping is afforded by means of side plates,which engage in stud-bolts screwed into the ends of the rollers. The clearance between the hook of the upper plate and the square ends of the lower plate should be great enough to allow a linear movement equal to the length of the span divided by three-thousand. (Merriman and Jacoby's "Bridge Design",page 225.) In many cases the sides of the segmental rollers near the top and bottom are parallel for a distance equal to about one-fourth of their height. The remaining portion of their sides is hollowed out to facilitate cleaning with a brush.

Another commendable type of roller-nest is that in which the rollers are long enough to support the end floorbeam. This type of roller-nest provides for a uniform expansion of the entire floor system.

In short-span bridges the rollers rest directly upon a steel bed-plate,which should have a minimum thickness of three-fourths of an inch. The bed-plates are fastened to the masonry by anchor bolts which should be at least one inch in diameter and nine to twelve inches long. These bolts are generally set in neat cement or sulphur. Sheet-lead three-eights to one-fourth of an inch in thickness should be placed between the masonry and the bed-

plate to uniformly distribute the pressure to the masonry.

In long spans the rollers usually rest upon T-rails, whose tops have been planed to a flat surface. These T-rails are riveted directly to the bed-plates.

PIN-CONNECTED DECK TRUSS.

A waterway can usually be spanned more economically with deck trusses than with through trusses if the required height for the waterway is small. This is true because the time of erection is less,and the cost of the masonry and the falsework is appreciably reduced. In addition to the advantage mentioned above,the wind bracing for the deck truss can be designed to have a greater efficiency at a less cost than the corresponding members of the through truss.

In general,the details of the two types of trusses mentioned above are very similar. The chords and main ties of the deck and through trusses are almost identical. There is,however,a considerable difference in some of the minor details. Only the more important details of the deck bridges,which differ from those of the through bridges,will be considered in the following discussion.

WIND BRACING.

The principal difference between the portal and sway bracing of the deck and through truss-bridges is that they extend diagonally across the space between the two trusses in deck bridges, while in through bridges,clearance is left to provide for the passage of the traffic. In a deck bridge the corresponding intermediate and end posts of the two trusses are cross-braced by two angles. The portal bracing is usually a little heavier than the cross-bracing,which is attached to the intermediate posts. In their deck bridges,the Illinois Central Railroad uses portals laced with angles. On account of the fact that no clearance is required between the trusses for the traffic,the portal and sway bracing is attached very closely to the ends of the intermediate and end posts. When

the bracing is attached near the ends of the posts,it produces no bending moment.

The top and bottom lateral bracing systems of deck bridges are similar to those of through truss-bridges,with the exception that the upper system of the deck truss corresponds to the lower system of the through truss-bridges.

FLOORBEAMS AND STRINGERS.

In deck bridges several different methods are used for connecting the floorbeams to the intermediate posts or upper chords. Sometimes they are attached to the intermediate posts so low that when the stringers are laid directly upon them,their upper flanges are on a level with the upper flanges of the top chord. When this is done the cross-ties are usually long enough so that the upper chord can aid the stringers in supporting them. The floorbeams of the Northern Pacific Railroad's standard deck bridges extend above the upper chord a distance equal to one-half of their height. In this case the stringers are fastened to the floorbeams in a manner similar to the method used in through bridges.

HIP-VERTICALS.

Below the floorbeam connection,the hip-verticals are sometimes composed of comparatively light loop-bars. These loop-bars support only the weight of one panel length of the bottom chord. In most cases,however,the hip-verticals are of uniform cross-section throughout their entire length.

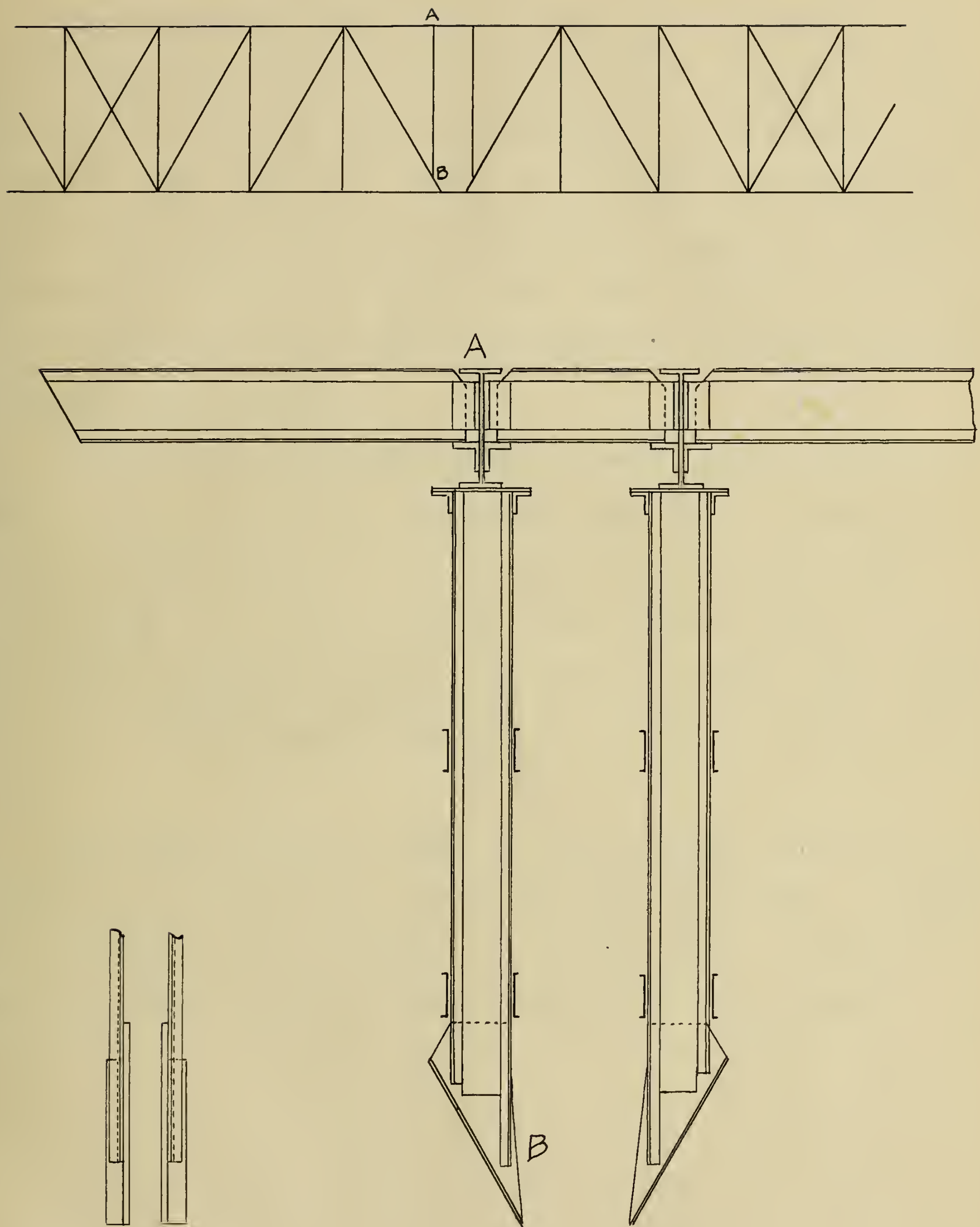

Fig.44.

CONNECTION OF TOP CHORDS.

Fig.44 shows a method used by the Illinois Central Railroad for making continuous the top chords of two adjacent bridges. In this case the vertical posts are attached to the bottoms of the end posts by means of bent plates. The floorbeams rest directly upon the tops of the vertical posts and the stringers and top chords are fastened to the webs of these beams. The function of the chord members in this particular case is to help hold in place the vertical post and the floorbeam.

The vertical posts at the end of each bridge are rigidly fastened together with heavy lateral bracing. This is essential; since any lateral movement of the post would prove disastrous to the connections. The distance between the vertical posts of two adjoining spans is usually three to four feet. A short chord is used to span this distance,and is fastened to the posts,as shown in Fig. 44.

When only one deck bridge is used to span a waterway,the abutments are often built on a level with the top chord. In such cases the members,which correspond to the end posts in through bridges,are tension members and may be composed of eye-bars.

THROUGH RIVETED TRUSSES.

Within the last few years the Americans have adopted the use of riveted trusses for spans from 150 to 175 feet. This is due to the improvements in riveting appliances and to a growing demand for rigidity in railroad structures. The principal advantage claimed for the rivet-connected over the pin-connected trusses is that the former make a stiffer bridge and one that will not rattle. The disadvantages are: that it takes a longer time for their erection; the stresses cannot be so accurately determined as in the pin-connected trusses; the deflections will produce twisting or bending stresses in the connections themselves; and they cost more than the pin-connected bridges. The eastern railroads,however,evidently concede that the advantages of the short riveted bridges outweigh their disadvantages. The Deleware,Lackawanna and Western Railroad specifies that riveted trusses shall be used for spans from 90 to 150 feet; while the New York Central and Hudson River Railroad requires that they shall be used for spans varying from 100 to 200 feet.

In rivet-connected trusses all of the members are composed either of plates and angles or of channels. Members that are not subjected to large stresses are usually composed of two pairs of angles,placed back to back and laced together,as is shown in Fig.8. A section similar to that shown in Fig.9 is often used. The intermediate posts usually consist of two channels whose flanges are turned inward. When the flanges of the diagonals and intermediate posts are turned inward,the members can,with little difficulty,be attached to the large connection plates at the joints.

A very common and efficient joint,in which the vertical and diagonal members meet at a panel point of the top chord,will now be described. Two large connection plates are riveted to the

webs of the channels composing the chord,the channels in this case having their flanges turned outward. The diagonals and verticals are attached to the inner sides of the connection plates. In any case the connection plates must be of sufficient size to allow space for the rivets required to fasten the members to them.

It is customary for all of the members meeting at a panel point of the bottom chord to be of the same width. This feature makes it easy to rivet the two large connection plates to the outside of the members,provided those members,which are composed of channels,have their flanges turned inward.

The connection of the floorbeams in riveted trusses is much simpler than the corresponding connection in pin-connected trusses; since it is not necessary to cut the webs of the floorbeams to provide clearance for the lower chord. Their webs are, however,sometimes spliced to provide for sufficient riveting space.

In panels where two diagonals cross each other,it is customary to cut one member and leave the other continuous at the intersection. In a few cases both members are cut at the intersection. This is not commendable practice; since there is nothing gained by cutting both members and it weakens the joint at the intersection. In short trusses the Howe system of bracing is used almost exclusively. In using this system the undesirable intersection of diagonals is avoided.

DECK RIVETED TRUSSES.

The composition of deck riveted trusses is almost identical with that of the through riveted trusses. The principal differences between these two types lies almost entirely in the system of wind bracing. The general arrangement and composition of the

wind bracing in deck riveted bridges and in deck pin-connected bridges is very similar. In fact, what has been said of the differences between the through and deck pin-connected trusses will apply equally well to the differences between the two types of riveted trusses.

CONCLUSION.

The details which have been discussed and illustrated in this thesis were taken from the standards for short-span bridges used by the various railroads in the United States. In addition to these railroad standards, the specifications of several of the large bridge companies have been investigated. It was found that a large number of railroads relied almost exclusively upon the details specified by the bridge companies; while others adhered rigidly to their own specifications. The details of most of the standards investigated were without serious fault. This is due to the fact that the railroads and bridge companies have employed the best bridge engineering experts in the country to work out efficient and economical designs for their standards.

In no respect has the treatment of this subject been exhaustive. Only the most common details used in short-span bridges have been considered. The details discussed, however, are representative of the best practice in bridge design.